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RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)						DATE February 2004	
APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA2 Applied Research			R-1 ITEM NOMENCLATURE Materials and Electronics Technology PE 0602712E, R-1 #17				
COST (In Millions)	FY 2003	FY2004	FY2005	FY 2006	FY 2007	FY 2008	FY 2009
Total Program Element (PE) Cost	414.437	465.450	502.044	486.485	495.035	496.154	496.821
Materials Processing Technology MPT-01	126.158	128.857	159.478	150.495	158.006	160.139	163.728
Microelectronic Device Technologies MPT-02	135.911	169.709	190.881	205.018	226.203	233.922	239.076
Cryogenic Electronics MPT-06	6.895	4.911	0.000	0.000	0.000	0.000	0.000
Beyond Silicon MPT-08	80.152	83.976	61.827	34.570	28.657	16.000	16.000
Biologically Based Materials and Devices MPT-09	65.321	77.997	89.858	96.402	82.169	86.093	78.017

(U) Mission Description:

(U) This program element is budgeted in the Applied Research Budget Activity because its objective is to develop technologies related to those materials, electronics, and biological systems that make possible a wide range of new military capabilities.

(U) The major goal of the Materials Processing Technology project is to develop novel materials, materials processing techniques, mathematical models and fabrication strategies for advanced structural and functional materials and components that will lower the cost, increase the performance, and/or enable new missions for military platforms and systems. Included in this project are efforts across a wide range of materials including: structural materials and devices, smart materials and actuators, functional materials and devices, and materials that are enabling for improvements in logistics (i.e., novel power sources, water purification, etc.).

(U) Advances in microelectronic device technologies, including digital, analog, photonic and microelectromechanical (MEMS) devices, continue to have significant impact in support of defense technologies for improved weapons effectiveness, improved intelligence capabilities and for enabling information superiority. The Microelectronics Device Technologies Project supports the continued advancement of these technologies through the development of performance driven advanced capabilities, exceeding that available through commercial sources, in

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electronic, optoelectronic and MEMS devices, semiconductor device design and fabrication techniques, and new materials and material structures for device applications. A particular focus for this work is the exploitation of chip-scale heterogeneous integration technologies that permit the optimization of device and integrated module performance.

(U) The Cryogenic Electronics project funds specific applications of thin-film electromagnetic materials in electronic devices and circuitry for military applications. Thin-film electromagnetic materials have reached a stage of development where specific applications can be identified in electronic devices and circuitry for military systems. This project draws to a close at the end of FY 2004, a reflection of the maturity level that DARPA has obtained in cryogenic electronic technology development and sub system insertion. Any further integration of this technology into weapon/sensor systems will be budgeted in the respective platform's PE and projects.

(U) The phenomenal progress in current electronics and computer chips will face the fundamental limits of silicon technology in the early 21st century, a barrier that must be overcome in order for progress to continue. The Beyond Silicon project explores alternatives to, or augmentation of, silicon based electronics in the areas of new electronic devices, new architectures to use them, new software to program the systems and new methods to fabricate the chips. Approaches include nanotechnology, nanoelectronics, molecular electronics, spin-based electronics, quantum computing, new circuit architectures optimizing these new devices, and new computer and electronic systems architectures.

(U) The Biologically Based Materials and Devices Project acknowledges the growing and pervasive influence of the biological sciences on the development of new materials and devices as well as the commensurate influence of materials, physics and chemistry on new approaches to biology and biochemistry. Contained in this project are thrusts in the application of biomimetic materials and devices for Defense, the development of biochemical materials for enhancement of performance, the development of multifunctional transducers based on biological membranes, and the application of magnetic materials in biological applications.

(U) <u>Program Change Summary:</u> <i>(In Millions)</i>	<u>FY 2003</u>	<u>FY 2004</u>	<u>FY2005</u>
Previous President's Budget	434.426	465.544	461.043
Current President's Budget	414.437	465.450	502.044
Total Adjustments	-19.989	-0.094	+41.001

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	<u>FY 2003</u>	<u>FY 2004</u>
Congressional program reductions	0.000	-19.994
Congressional increases	0.000	19.900
Reprogrammings	-0.250	0.000
SBIR/STTR transfer	-19.739	0.000

(U) Change Summary Explanation:

FY 2003	Decreases reflect SBIR transfer and minor reprogramming.
FY 2004	Decrease reflects congressional program reductions to Biochemical Materials (MPT-09), Intelligent Digitization of Analog Sensors (MPT-02) and undistributed reductions offset by adds in the areas of optoelectronics, strategic and advanced materials, cryo-power, heat actuated coolers, 3D structures, friction stir welding and nanotechnology.
FY 2005	Increase reflects additional efforts in the functional materials programs, additional microelectronics efforts, new biology efforts and additional funds being added to the Focused Quantum Systems Initiative.

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APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA2 Applied Research			R-1 ITEM NOMENCLATURE Materials and Electronics Technology PE 0602712E, Project MPT-01				
COST (In Millions)	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	FY 2008	FY 2009
Materials Processing Technology, MPT-01	126.158	128.857	159.478	150.495	158.006	160.139	163.728

(U) **Mission Description:**

(U) The major goal of this project is to develop novel materials, materials processing techniques, mathematical models and fabrication strategies for advanced structural and functional materials and components that will lower the cost, increase the performance, and/or enable new missions for military platforms and systems. Included in this project are efforts across a wide range of materials including: structural materials and devices, smart materials and actuators, functional materials and devices, and materials that are enabling for improvements in logistics.

(U) **Program Accomplishments/Planned Programs:**

	FY 2003	FY 2004	FY 2005
Structural Materials and Devices	32.828	34.000	45.100

(U) The Structural Materials and Devices program is exploiting emerging material science concepts and processing approaches to tailor the properties and performance of structural materials and devices to DoD requirements. Thrusts in this area include new concepts for ultra lightweight materials, amorphous and multi-functional materials for lowering the weight and increasing the performance of aircraft, ground vehicles, and spacecraft structures. Approaches are also being developed for reducing the risk of introducing new materials in defense acquisitions and maintaining them in the field. Techniques are being established for assessing damage evolution and predicting future performance of the structural materials in Defense platforms/systems through physics-based models and advanced interrogation tools. New, low cost processing and fabrication techniques are also being developed to enable expanded use of new materials and structures in Defense applications as well as to produce novel materials that cannot be made through conventional processing approaches.

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(U) Program Plans:

- Develop multifunctional materials concepts designed to provide significant improvement in the capabilities of Defense systems by providing additional functions (e.g., self-healing, thermal control, blast protection, and power) to load bearing structures, quantify their performance and fabricate specific prototype systems.
- Develop and verify models that predict bulk amorphous metal formation and behavior; use these models to produce bulk amorphous materials with superior properties (including increased fracture toughness and high strain rate behavior and long-term corrosion resistance in saline environment) over crystalline material.
- Demonstrate fabrication (forming, joining, etc.) technologies that yield bulk amorphous metals suitable for Defense applications, especially those that require high fracture toughness, even at high strain rates, and quantify the impact of using bulk amorphous materials in construction of land vehicles and naval vessels.
- Demonstrate and validate solutions to critical technical issues for the accelerated insertion of materials that will allow designers to cut the insertion time of new materials by over 50 percent using materials of high value to DoD (turbine metals, aircraft structures).
- Apply the accelerated insertion methodology to new materials that, if inserted, will significantly improve Defense systems.
- Explore techniques for large volume, low cost synthesis and assembly of nanomaterials and nanotubes with controlled attributes that are suitable for high toughness fibers and reinforcements; demonstrate these reinforcement concepts in structural composites for advanced blast and ballistic damage tolerance.
- Develop models, mathematical techniques and novel sensors that when integrated with sensor data will capture the physics of failure and behavior prediction in materials suitable for assessing in-situ damage accumulation and will also provide current state awareness and structural performance prediction for Defense systems.
- Demonstrate the use of flight information to predict life and failure of critical structural components.
- Demonstrate novel, cost effective processing routes for structural materials of interest to Defense, especially titanium.
- Demonstrate novel and reproducible process routes for directed, localized and controlled microstructure modification to achieve substantial improvements in structural material properties of interest to Defense, including bronze castings for Navy applications.
- Explore concepts and demonstrate materials technologies for large, ultra-lightweight and controllable space structures.
- Develop unique, three dimensional processing approaches for making materials and structures of interest to DoD (GRIN Lenses, high temperature structures, high temperature actuators).

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		FY 2003	FY 2004
Smart Materials and Actuators		28.930	32.007
		37.000	

(U) In this thrust, smart materials, sensors and actuators for the control of the aerodynamic and hydrodynamic behavior of military systems are being developed and demonstrated to increase performance and lower detectability of aircraft, helicopters, and submarines. New piezoelectric materials are being developed that will dramatically increase the performance of Navy sonar/systems. "Intrinsically smart" materials that provide self-diagnosis and/or self-repair will be developed as well. Machines are being developed that will increase the individual soldier's physical capabilities by augmenting speed, strength, and endurance. New combinations of advanced materials, devices, and structural architectures are being developed to allow military platforms to morph or change shape to adapt optimally to changing mission requirements and unpredictable environments. New materials and devices will enable the military to function more effectively in the urban theatre of operations.

(U) Program Plans:

- Demonstrate enhanced Naval sonar device/system performance using piezocrystals over a spectrum of representative applications on the laboratory scale, and for a selected few applications on the field scale.
- Develop exoskeleton architectures that are kinematically and dynamically compatible with human physiology.
- Design, demonstrate and validate an integrated, untethered, and self-powered exoskeleton system for augmenting the locomotion and strength of soldiers. The interface of the machine and human will be dramatically enhanced by the development of novel sensor architectures and control algorithms.
- Develop and demonstrate novel fluidic and mechanical devices, and their associated driving electronics that exploit smart material transducers in order to create new high power actuators for a variety of military applications.
- Develop, design and test the actuators, materials, and control architectures necessary for achieving precise shape change in an airframe to demonstrate the advantages and enable capabilities afforded by the ability to change shape (morphing).
- Extend morphing concepts to expand military capabilities of air vehicles, transatmospheric vehicles and orbiting systems.
- Develop ultra-light high temperature capable materials systems for hypersonic vehicles incorporating magnetic features to enable reduced thermal load, boundary layer control and virtual shape control.
- Develop materials and devices to enable personnel access to rooftops and upper story windows and, in cooperation with the Services, develop fieldable systems for use in urban operations.

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- Develop materials, devices, and systems for urban conflict including compact, expandable barriers, tamper resistant or tamper evident door and window coverings, and traction reducing agents for impeding foot and wheeled traffic.

	FY 2003	FY 2004	FY 2005
Functional Materials and Devices	25.000	25.000	37.200

(U) In this program, new materials and concepts are being applied to the development of functional materials and devices. This includes advanced magnetic materials for high sensitivity, magnetic field sensors; non-volatile, radiation-hardened magnetic memories with very high density, short access time, infinite cycleability and low power; novel materials and device structures for high frequency acoustic imaging; and electroactive polymers for sensing, actuating, and analog processing. New permanent magnetic materials with significantly higher magnetic strength and higher operating temperature for motors, generators, flywheels, bearings and actuators are also being explored. Unique multifunctional fibers that can be woven into fabrics are being developed. Engineered materials (metamaterials) are being developed that provide dramatically new electromagnetic behavior across the complete array of Defense applications. Technology for the mask-less, direct-write of mesoscopic integrated conformal electronics will enable the three-dimensional integration of both active and passive components, significantly reducing the size, weight and cost of integrated electronics functions (circuits, batteries, antennae, etc.).

(U) Program Plans:

- Demonstrate frequency and phase agile antennas, filters, phase shifters, and matching elements and transition to Army and Navy communication and remote sensing applications.
- Demonstrate both 1Mbit standalone Magnetic Random Access Memory (MRAM) at high density and high speed and lower density radiation-hard embedded memory and transition to Navy Strategic Programs and DTRA.
- Demonstrate the ability to direct write mesoscale (10 microns to 1 mm) electronic circuitry, both passive and active (transistors, filters, etc.), conformally, on low temperature substrates (plastic, paper, etc.), using computer aided design/computer aided manufacturing (CAD/CAM) software.
- Develop and demonstrate novel magnetic meta-materials including: 1) high temperature, high strength soft magnetic materials for rotor and stator applications in turbine environments; and 2) permanent magnets with superior energy products (> 30 MGOe for isotropic systems and > 60 MGOe for anisotropic systems) for DoD motor applications.

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- Develop and demonstrate novel microwave meta-materials (including artificial ferrites, nanocomposite ferroelectrics, artificial magnetodielectrics, and negative index materials) that will enable novel antenna and radar designs with reduced size and improved bandwidth and efficiency.
- Develop smart, multifunctional fibers (e.g., fibers that incorporate power, electro-magnetic behavior, actuating and sensing functions) that may be woven into textiles to provide revolutionary capability for warfighter uniforms and equipment; for autonomous vehicles, and space structures.
- Develop and demonstrate novel materials that can be remotely switched between two stable electromagnetic and/or structural configurations.
- Extend the frequency of operation and/or operational bandwidth of “negative index” or “left handed” materials to demonstrate novel RF and optical applications for Defense.
- Develop new functional material amenable to slowing, storing and manipulating light.

	FY 2003	FY 2004	FY 2005
Materials for Logistics (Air, Water, Power)	34.000	32.900	40.178

(U) This thrust will apply novel materials and structures to reduce the logistics burden of the warfighter in the field. New materials and concepts for increasing the availability of portable power to the soldier are being investigated, as are approaches for deriving power from the environment for soldiers and sensors. Novel approaches for direct energy conversion from thermal sources such as submarine nuclear reactors are also being examined. New materials and designs will also be applied to the development of novel mesoscale engines (e.g., Stirling, water-lubricated steam engines) that will provide needed power on the battlefield. Hybrid superconducting/cryogenic components will provide a new paradigm for power electronics for the “all electric” platforms of the future. The feasibility of open ocean, littoral and freshwater prototype fuel cell systems, capable of generating continuous, unattended electrical power for greater than 10 years, will be investigated. Other approaches to enzymatic based energy sources will also be examined. Finally, materials technologies will also be employed in novel approaches for obtaining and purifying water in the field as well as air purification.

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(U) Program Plans:

- Design, develop, and demonstrate portable power sources in the 20 Watt power range suitable for several mission scenarios including: 1) a 3 hour micro air vehicle reconnaissance mission (1000 Whrs/kg); 2) a 3 day land warrior mission (2000 Whrs/kg); and 3) a 10 day special operation forces mission (3000 Whrs/kg).
- Develop and demonstrate enabling direct thermal to electric conversion technologies with potential for high (> 20%) conversion efficiencies and high (> 1 W/cm²) power densities for DoD and commercial power generation applications.
- Demonstrate concepts for highly power-dense, man-portable kilowatt generators that will reduce the logistics burden for the soldier in the field.
- Demonstrate efficient, low cost, 200 watt Stirling engine for Defense applications, including powering of small, motorized vehicles.
- Develop and demonstrate unique, energy-saving concepts for obtaining water from non-traditional sources (water-from-air, combusted hydrocarbons, and urine) for the individual warfighter and small groups of soldiers.
- Develop and demonstrate novel technologies for low-power purification of any brackish or salty brine solution.
- Demonstrate materials and components for a hybrid superconducting power system for a terrestrial (>5 MW) application that has high efficiency and reliability and the potential for significantly reduced size (10x) and weight (5x).
- Develop novel rectifying antenna approaches that will allow efficient beaming of power between spacecraft.
- Demonstrate processes that can convert military waste to usable military logistic fuels.
- Increase the power density of small electric motors and hydrocarbon powered engines by a factor of more than 10 times.
- Design bioelectrocatalysts that are compatible to both the environment of the fuel cell, the electrolyte, and electron transport to the electrode.
- Develop sediment and water column fuel cell prototype systems; investigate systems concepts for fuel cell powered prototype surveillance platforms capable of maintaining a sustained presence.

	FY 2003	FY 2004	FY 2005
Strategic Material Manufacturing	3.400	0.000	0.000

(U) Program Accomplishments:

- Continued to develop new manufacturing approaches for cutting tools and other ceramics used for Defense applications.

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	FY 2003	FY 2004	FY 2005
Heat Actuated Coolers	1.000	1.200	0.000

(U) Program Plans:

- Continue to develop compact, lightweight microtechnology-based cooling systems to take advantage of the availability of portable cooling in military and civilian applications where electric power is not available, but waste heat is plentiful.

	FY 2003	FY 2004	FY 2005
Friction Stir Welding	1.000	1.200	0.000

(U) Program Plans:

- Continue to investigate the applicability of using Friction Stir Welding to join amorphous alloys without recrystallization.

	FY 2003	FY 2004	FY 2005
Advanced Materials Research Institute	0.000	1.800	0.000

(U) Program Plans:

- Develop nano devices fabricated by bottoms-up fabrication techniques that will form the basis for novel sensors as well as have the potential for information storage.

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	FY 2003	FY 2004	FY 2005
Materials Science Technology	0.000	0.750	0.000

- (U) Program Plans:
- Continue development of a training program for advanced composite materials that integrates university and community college programs with industry needs to develop a comprehensive curriculum to meet the growing demand for a trained workforce and identify best practices for the industry.

(U) **Other Program Funding Summary Cost:**

- Not Applicable.

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APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA2 Applied Research			R-1 ITEM NOMENCLATURE Materials and Electronics Technology PE 0602712E, Project MPT-02				
COST (In Millions)	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	FY 2008	FY 2009
Microelectronic Device Technologies, MPT-02	135.911	169.709	190.881	205.018	226.203	233.922	239.076

(U) **Mission Description:**

(U) Advances in microelectronic device technologies, including digital, analog, photonic and microelectromechanical (MEMS) devices, continue to have significant impact in support of defense technologies for improved weapons effectiveness, improved intelligence capabilities and enhanced information superiority. The Microelectronics Device Technologies Project supports the continued advancement of these technologies through the development of performance driven advanced capabilities, exceeding that available through commercial sources, in electronic, optoelectronic and MEMS devices, semiconductor device design and fabrication techniques, and new materials and material structures for device applications. A particular focus for this work is the exploitation of chip-scale heterogeneous integration technologies that permit the optimization of device and integrated module performance.

(U) **Program Accomplishments/Planned Programs:**

	FY 2003	FY 2004	FY 2005
Adaptive Focal Plan Arrays (AFPA)	3.556	6.775	7.503

(U) The goal of this program is to demonstrate high-performance focal plane arrays that are widely tunable across the entire infrared (IR) spectrum (including the short, middle and long-wave infrared bands), thus enabling "hyperspectral imaging on a chip." The Adaptive Focal Plane Array (AFPA) program will also allow for broadband Forward Looking Infrared (FLIR) imaging with high spatial resolution. These AFPAs will be electrically tunable on a pixel-by-pixel basis, thus enabling the real-time reconfiguration of the array to maximize either spectral coverage or spatial resolution. The AFPAs will not simply be multi-functional, but rather will be adaptable by means of electronic control at each pixel. Thus, the AFPAs will serve as an intelligent front-end to an optoelectronic microsystem. The AFPA program outcome will be a large format focal plane array that provides the best of both FLIR and Hyper-Spectral Imaging (HSI).

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- (U) Program Plans:
- Develop component technology (tunable IR photodetectors).
 - Integrate detector array.
 - Demonstrate pixel-by-pixel electrical tunability in IR.
 - Demonstrate AFPA prototype field using a large format array.

	FY 2003	FY 2004	FY 2005
Vertically Interconnected Sensor Arrays (VISA)	11.356	9.628	8.900

(U) The Vertically Interconnected Sensor Arrays (VISA) program will develop and demonstrate vertically interconnected, focal plane array (FPA) read-out technology capable of more than 20-bits of dynamic range, enabling significant advances in the functionality of infrared systems. The extremely high dynamic range will be accomplished by novel multilayer read-out circuits. These circuits will enable imaging at more than 20-bits of dynamic range, whereas the current state of the art is over an order of magnitude lower. Adaptive read-out circuits will be vertically connected to individual detectors in either monochromatic or stacked multicolor 2D staring arrays. The ability to bring signal directly from the detectors to the read-outs (i.e., vertical interconnection) without first going through row-column multiplexers will allow for high frame rates concurrently with high resolution images.

- (U) Program Plans:
- Develop a wafer stacking process incorporating high-density vias and design novel circuits that enable high frame rates, counter measure hardening and adaptive signal processing functions on a concept test chip.
 - Demonstrate a high dynamic range Analog/Digital VISA technology based sensor designed with advanced high performance circuit architecture implemented in stacked semiconductor process with high-density interconnections.

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	FY 2003	FY 2004	FY 2005
Imaging Coherent Optical Radar	0.000	9.000	11.000

(U) This program, utilizing extremely high speed imaging nanotechnology, will develop new coherent optical radar cameras, up to GHz sampling rate, for imaging/non-imaging high sensitivity vibrometry, Doppler and intensity measurements, and achieve extremely fast high performance imaging in small, low power, reduced thermal load, producible devices for insertion throughout the military community. The technology will do what radar does, but with an optical carrier and optical resolution.

(U) Program Plans:

- Obtain vibrational (acoustic) spectral images of targets of interest.
- Detect relative motion of objects and materials (moving target identification-MTI).
- Develop coherent heterodyne local oscillator concepts and coherent single photon counting concepts.
- Demonstrate nanofabrication techniques for realizing broadband coherent optical sources with tailored spectral output for imaging, communication, targeting and countermeasure applications.

	FY 2003	FY 2004	FY 2005
3-D Microelectromagnetic RF systems (3-D MERFS)	0.000	3.480	4.020

(U) The 3-D Microelectromagnetic RF systems (3-D MERFS) program, formerly Highly Integrated Millimeter Wave (MMW) Electronically Scanned Array (ESA), will investigate the possibility of making complete millimeter wave active arrays on a single or a very small number of wafers. The program will exploit new technologies being developed commercially that allow GaAs active components to be placed on Si wafers, and advances in InP and SiGe that may allow an entire MMW Electronically Scanned Array (ESA) to become very highly integrated on a sandwich of wafers. At lower frequencies, the large spacing between radiating elements precludes the efficient use of the wafer real estate for fabricating the entire ESA, but at Ka and W- bands, the element spacing is small enough to allow an ESA to be made with active transmit/receive chips and control circuits on one layer, radiators on another, and a feed system on a third. This could potentially make them very cheap, compact, lightweight and reliable. This would enable the development of new MMW ESAs of a six inch diameter or less for seekers, communication arrays

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for point-to-point communications, sensors for smart munitions, robotics and small remotely piloted vehicles. This program will build upon technology which was developed under the Vertically Interconnected Sensor Array.

- (U) Program Plans:
- Survey the emerging commercial MMW technology base and identify the best candidate processes for the MMW ESA application.
 - Develop the optimal ESA architectures for wafer fabrication.
 - Determine requirements for MMW ESAs that match the expected performance.
 - Design, build, and test candidate ESA designs.
 - Design, build, and test full ESA seeker or other system using the wafer fabrication technology.

	FY 2003	FY 2004	FY 2005
Analog Optical Signal Processing (AOSP)	12.557	11.538	8.500

(U) Analog Optical Signal Processing (AOSP) will significantly enhance the performance of, and enable entirely new capabilities and architectures for tactical and strategic RF systems. The program will expand the dynamic range-bandwidth and time-bandwidth limits by a factor of 1,000 through the introduction of analog optical signal processing components into the system front ends.

- (U) Program Plans:
- Perform analysis of analog signal characteristics of military RF systems.
 - Create, model and simulate new photonic-based optical signal processing techniques of ultra-high bandwidth analog signals.
 - Evaluate anticipated system performance improvements due to novel signal processing algorithms and determine the resulting photonic component performance requirements.
 - Test and evaluate signal processing techniques of analog signals.
 - Evaluate photonic component performance requirements.
 - Design, fabricate and test individual photonic components capable of meeting RF signal processing requirements.
 - Determine the most promising approaches for development of integrated, chip-scale components using new materials and processing technologies.

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- Determine interface requirements.
- Evaluate the suitability of the new components for use in prototype modules.
- Down-select to the most promising approaches and begin prototype module assembly.
- Construct testbeds capable of fully characterizing the photonic-based RF signal processing components.

	FY 2003	FY 2004	FY 2005
Advanced Precision Optical Oscillator (APROPOS)	0.000	3.929	4.904

(U) The APROPOS program, formerly titled Precision Optical Oscillators, will leverage advances in materials and lasers to develop new precision microwave-stable local oscillators with extremely low phase noise (up to 50 dB better than the current state of the art) at small offsets from microwave carrier frequencies. This capability will enhance performance of radar, electronic warfare and communications systems in weak signal detection at increased stand off ranges, slow moving target detection, clutter suppression, and electronic warfare "fingerprinting (specific emitter identification).

(U) Program Plans:

- Improve phase noise power spectral density by 25 dB and prove the utility of multi-line laser cavities and opto-electronic oscillators. Identify and characterize environmental susceptibilities and define path to 50 dB improvement over state of the art.
- Demonstrate 50 dB improvements in lab setting.
- Develop miniaturization approach and packing concept to mitigate environmental susceptibilities.
- Miniaturize devices in ruggedized packages.
- Demonstrate performance in tactical environments insert in system testbeds.

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	FY 2003	FY 2004	FY 2005
Advanced Digital Receiver	0.000	0.000	2.800

(U) The Advanced Digital Receiver program will leverage and improve Analog to Digital Converter (ADC) technology to develop Digital Receivers with greatly enhanced performance. Goals include reducing size, weight and power by an order of magnitude, enhancing programmability, flexibility and performance, reducing life cycle cost, and developing ADCs with 16 effective bits, 100 MHz instantaneous bandwidth and >100 dB spurious free dynamic range (SFDR).

(U) Program Plans:

- Demonstrate 1st Pass Sigma-delta Modulator in test Fixture.
- Demonstrate 2nd Pass Sigma-delta Modulator in test Fixture with ADC-DAC Iteration 1.
- Demonstrate Real-time Digital Receiver Operation by Benchtop Integration of Best Sigma-delta Test Fixture and WAR Decoder Test Fixture.
- Demonstrate 3rd Pass Sigma-delta Modulator in test fixture with ADC-DAC Iteration 2.
- Demonstrate Real-time Digital Receiver Module Prototype (provide 5 modules).

	FY 2003	FY 2004	FY 2005
Chip Scale Atomic Clock	15.225	15.930	15.840

(U) The Chip Scale Atomic Clock will demonstrate a low-power chip scale atomic-resonance-based time-reference unit with stability better than one part per billion in one second. Application examples of this program will include the time reference unit used for GPS signal locking.

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- (U) Program Plans:
- Demonstrate feasibility and theoretical limits of miniaturization of cesium clock.
 - Demonstrate subcomponent fabrication, including atomic chamber, excitation and detection function.
 - Demonstrate design and fabrication innovation for atomic-confinement cell and for GHz resonators suitable for phase locking or direct coupling with atomic confinement cell.

	FY 2003	FY 2004	FY 2005
Technology Efficient, Agile Mixed Signal Microsystem (TEAM)	15.036	14.362	14.712

(U) Technology for Efficient, Agile Mixed Signal Microsystems (TEAM) will enable fabrication of high performance mixed signal systems-on-chip that will be the core of the embedded electronics in new platforms that are constrained by size and on-board power.

- (U) Program Plans:
- Develop and demonstrate nanoscale silicon-based structures and associated fabrication processes to achieve high-speed analog/RF functions.
 - Optimize device and process parameters for high speed mixed signal circuits.
 - Produce test devices for analog/RF parameter extraction.
 - Demonstrate Complementary Metal Oxide Semiconductor (CMOS) compatible fabrication processes that can yield integration levels greater than 10,000 nanoscale devices.
 - Initiate highly parallel densely interconnected architectures with micron-sized vias penetrating stacks of detectors, analog, mixed signal and digital circuits.
 - Demonstrate operation of high performance mixed signal circuits based on nanoscale devices.
 - Demonstrate low noise interface and high isolation (up to 100 db) between high performance analog circuits and associated digital signal processing.
 - Fabricate mixed signal systems on chip with nano-scale transistors.

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		FY 2003	FY 2004
Technology for Frequency Agile Digitally Synthesized Transmitters (TFAST)		26.104	16.000

(U) The TFAST program (Ultra High Speed Circuit Technology) will develop super-scaled Indium Phosphide (InP) Heterojunction Bipolar Transistor (HBT) technology compatible with a ten-fold increase in transistor integration for complex mixed signal circuits. Phase I will establish the core transistor and circuit technology to enable the demonstration of critical small scale circuit building blocks suitable for complex mixed signal circuits operating at speeds three times that currently achievable and ten times lower power. Phase II will extend the technology to the demonstration of complex (more than 20,000 transistors) mixed signal circuits with an emphasis on direct digital synthesizers for frequency agile transmitters.

(U) Program Plans:

- Develop material and process technology for super-scaled InP double heterostructure bipolar transistors (DHBTs). Technical approaches will leverage the process technology used in the silicon, and silicon germanium, industry to produce a planar, highly scalable InP HBT.
- Extend the core DHBT and interconnect technology with the implementation of complex mixed signal circuits.
- Develop super-scaled InP HBT processing technology for 0.25 micron and below.
- Develop high current, planar, InP HBTs compatible with high levels of integration.
- Develop greater than 100 GHz mixed signal circuit building blocks.
- Demonstrate record performance InP HBTs in a planar process for complex mixed signal circuits.
- Demonstrate critical mixed signal building block circuit operating at more than 100 GHz.
- Develop circuit designs for direct digital frequency synthesizers (DDS) operating with clock speed up to 30 GHz.
- Define circuit designs and layouts for mm-wave DDS and related complex mixed signal circuits.
- Develop full circuit capability using super-scaled InP HBTs in complex (more than 20,000 transistor) circuits.
- Established device models and critical design rules.

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	FY 2003	FY 2004	FY 2005
Clockless Logic	0.000	4.367	5.643

(U) The Clockless Logic program goal is to develop techniques to reduce the amount of design resources required in chip design and significantly reduce the power and noise to provide improved system operation. Clockless methods will provide more efficient designs especially for military systems with demanding space, weight, power, and noise constraints.

(U) Program Plans:

- Develop method for design of complex chips using clockless logic.
- Enhance tools and methods for design of clockless logic circuits and systems.
- Identify and design complex chips with significant potential for improved system performance and reduced design times.
- Apply clockless design methods to programmable logic devices to provide significant potential for improved system performance and reduced design times.
- Demonstrate performance enhancements of complex chip enabled by clockless logic in radar or similar testbed.

	FY 2003	FY 2004	FY 2005
Carbon Nanotube Induced Reactions	0.000	0.000	3.308

(U) The Carbon Nanotube Induced Reactions program will develop a technology base for making use of the nanotube-microwave interactions that allows (1) intense heat release at a rapid rate and (2) microwave absorption with “radar-transparent” applications. It is envisioned that interactions between carbon nanotubes and electromagnetic radiation can be exploited to provide (1) rapid energy release at several times or more of the input energy and (2) magnetic radar absorbing material formed by polymers loaded with carbon nanotubes.

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(U) Program Plans:

- Develop technologies to understand the cascade of the fundamental physical and chemical processes that arise during microwave irradiation of single wall carbon nanotubes (SWNTs) under conditions which lead to intense light bursts and high thermal energy output to the surroundings.
- Identify contributing underlying mechanisms, whatever their detailed nature, e.g., nuclear, chemical or other processes, through time resolved spectroscopies and particle emission measurements combined with detailed changes in the structural and chemical nature of the SWNTs induced by irradiation.
- Investigate novel microwave absorbing materials based on carbon nanotube-loaded polymers.

	FY 2003	FY 2004	FY 2005
Design Tools for 3-Dimensional Electronic Circuit Integration	0.000	9.000	10.500

(U) This program will develop a new generation of CAD tools to enable the design of integrated three-dimensional electronic circuits. The program will focus on methodologies to analyze and assess coupled electrical and thermal performance of electronic circuits and tools for the coupled optimization of parameters such as integration density, cross talk, interconnect latency and thermal management. The goals of this initiative are to develop a robust 3-D circuit technology through the development of advanced process capabilities and the design tools needed to fully exploit a true 3-D technology for producing high performance circuits. The deliverables from this program will have a significant impact on the design of mixed signal (digital/analog/RF) systems and Systems-on-a-Chip for high performance sensing, communication and processing systems for future military requirements.

(U) Program Plans:

- Apply 3D design tools to test structure.
- Fabricate and test structures.
- Verify models against data.

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	FY 2003	FY 2004	FY 2005
Chip-to-Chip Optical Interconnects	0.000	3.086	7.000

(U) Continuing advances in integrated circuits technology are expected to push the clock rates of CMOS chips into 10GHz range over next five-to-seven years. At the same time, copper-based technologies for implementing large number of high speed channels for routing these signals on a printed circuit board and back planes are expected to run into fundamental difficulties. This performance gap in the on-chip and between-chip interconnection technology will create data throughput bottlenecks affecting military-critical sensor signal processing systems. To address this pressing issue, the proposed program will develop optical technology for implementing chip-to chip interconnects at the board and back plane level.

- (U) Program Plans:
- High-linear density, low loss optical data transport channels that can be routed to ~1 meter distance in a geometric form factor compatible with a printed circuit board.
 - High speed (faster than 10 GBps), low power (less than 50 mW) optical transmitter/receivers.
 - Integration of optical transmitters/receivers and optical data paths with electronic packaging and manufacturing approaches.

	FY 2003	FY 2004	FY 2005
Multiple Optical Non-redundant Aperture Generalized Sensors (MONTAGE)	0.000	0.000	4.367

(U) The MONTAGE program aims to implement a revolutionary change in the design principles for imaging sensor systems, enabling radical transformation of the form, fit, and function of these systems for a wide variety of high-value DoD applications. Significant improvements in the performance, affordability, and deployability of imaging sensor systems will obtain from rational co-design and joint optimization of the imaging optics, the photo sensor array and the post-processing algorithms. By reaching well beyond conventional designs, MONTAGE sensors will realize optimal distribution of information handling functions between analog optics and digital post-detection processing.

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(U) Specific demonstrations include reduction of the depth/thickness of an imaging sensor by an order of magnitude without compromising its light gathering ability or resolution. This dramatic reduction in thickness will then allow the imaging sensors to be deployed conformally around a curved surface of a platform (e.g., UAV, tank, or helmet). Furthermore, the flexibility generated by the incorporation of post-processing in the image formation will allow variable resolution image formation, which in turn reduces the data load for subsequent image exploitation and communication systems. Advanced post-processing algorithms will support video operation at frame rates in excess of 10 frames per second using standard computing platforms.

(U) Program Plans:

- Develop novel optical designs allowing depth reduction by 10X.
- Concurrent with optics design, develop sensor array design and post-processing algorithms to realize signal-to-noise ratio and resolution of comparable optical aperture.
- Demonstrate ability to allocate highest spatial resolution to specified regions of interest in the image while maintaining medium resolution elsewhere.
- Develop architectures for surpassing detector size-limited resolution and potentially exceed optically limited resolution.
- Demonstrate operation of a thin imaging system deployed on a curved surface.
- Demonstrate real time performance of thin imaging systems in representative DoD applications with performance evaluated using application-specific metrics for image quality, sensor cost, power consumption, mechanical properties.

	FY 2003	FY 2004	FY 2005
High Frequency Wide Band Gap Semiconductor Electronics Technology	25.279	25.000	22.297

(U) The High Frequency Wide Band Gap Semiconductor Electronics Technology program is developing wide band gap semiconductor technology and will demonstrate high performance, cost effective high power electronic devices that exploit the unique properties of wide band gap semiconductors. This program will develop low defect epitaxial films, high yield fabrication processes, and device structures for integrated electronic devices for emitting and detecting high power radio frequency/microwave radiation, and high power delivery and control.

(U) Program Plans:

- Develop bulk and surface process technologies for reducing or mitigating crystallographic defects in wide band gap materials.

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- Develop semi-insulating substrates for high frequency devices.
- Design high power enclosures for microwave electronic assemblies.
- Demonstrate large periphery high power devices suitable for microwave and mm-wave operation.
- Demonstrate process reproducibility and minimization of yield limiting factors.
- Establish device characterization for very high power solid-state amplifiers.
- Demonstrate 100 mm SiC and wide band gap alternate substrates with less than 80 micropipe/cm² and resistivity 10⁶ ohms-cm.
- Demonstrate epitaxial processes that yield + 3 percent uniformity over 75 mm wide bandgap substrates.
- Initiate thermal management study to determine best packaging approach for high power, high frequency microwave and millimeter wave transistors.
- Demonstrate 100 mm SiC and wide band gap alternate substrates with less than 40 micropipe/cm² and resistivity 10⁷ ohms-cm.
- Demonstrate epitaxial processes that yield + 1 percent uniformity over 100 mm wide bandgap substrates.
- Identify fabrication processes for robust microwave and mm-wave devices. Identify thermal management concepts to sustain more than 1 KW/cm² power density in high power devices.
- Optimize wide band gap semiconductor materials to achieve 100 mm substrates with less than 10 micropipe/cm² and resistivity greater than 10⁷ ohms-cm at room temperature.
- Demonstrate fabrication processes for robust microwave and mm-wave devices with RF yields greater than 70 percent.
- Demonstrate thermal management concepts to sustain more than 1KW/cm² power density in high power devices.

	FY 2003	FY 2004	FY 2005
High Power Wide Band Gap Semiconductor Electronics Technology	11.805	12.314	14.000

(U) An initiative in High Power Wide Band Gap Semiconductor Electronics Technology will develop components and electronic integration technologies for high power, high frequency microsystem applications based on wide band gap semiconductors.

(U) Program Plans:

- Develop low defect conducting Silicon Carbide (SiC) substrate consistent with yielding 1 cm² devices.
- Develop lightly doped, thick (more than 100 micron) SiC epitaxy with low defects to enable 10 kV class power devices.

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- Develop low on-state resistance SiC diodes capable of blocking 10 kV.
- Demonstrate SiC wafer and thick epitaxy with less than 1.5 catastrophic defects per cm² consistent with 10 kV reverse blocking.
- Initiate work on Megawatt class SiC power device able to switch at more than 100 kHz.
- Initiate work on packaging of high power density, high temperature SiC power electronics.
- Demonstrate megawatt Class SiC power devices.
- Demonstrate high power density packaging for greater than 10 kV operation.
- Develop integrated power control logic compatible with high temperature and power SiC power devices.

	FY 2003	FY 2004	FY 2005
Robust Integrated Power Electronics (RIPE)	0.000	11.000	10.000

(U) The RIPE program, formerly titled Smart Power Based on Heterogeneous Integration of Silicon and Silicon Carbide Electronics, will develop new semiconductor materials, devices, and circuits that enable highly compact, highly efficient electronic power converter modules. These new modules will be capable of providing up to 50kW of power per module at a power density of 500W/cubic inch. Based on fundamental material properties, the new power modules will be capable of operating in harsh environments. These new power converters will reduce the launch weight of space-based platforms by hundreds of pounds and will enable new modes of operation where the power conversion is done at the point of load and provides high quality power to payloads. Application of RIPE on Naval surface ships would result in a significant reduction of power supply weight; allowing for additional electronic components and/or weapons.

- (U) Program Plans:
- Perform concept study to define opportunities for smart power and the potential for integrating silicon carbide, or other wide bandgap semiconductor, with silicon electronics.
 - Identify key technical challenges and quantify impact of potential platforms.
 - Identify compelling applications.
 - Select and optimize wide bandgap materials and processes for smart power circuits.

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- Develop integration techniques for silicon carbide, or other wide bandgap semiconductor, onto silicon and/or silicon onto silicon carbide.
- Develop low on-resistance, fast switching silicon carbide power devices with hybrid control electronics.

	FY 2003	FY 2004	FY 2005
UltraBeam	0.000	0.000	3.087

(U) The UltraBeam program involves conversion of femtosecond duration ultraviolet laser light pulses to x-rays and the study of intense x-ray pulse propagation in various media.

(U) Program Plans:

- Validate the scientific feasibility of the conversion and propagation processes.
- Demonstrate a working laboratory model involving higher beam energies and shorter pulse durations.

	FY 2003	FY 2004	FY 2005
Submillimeter Wave Imaging FPA Technology (SWIFT)	0.000	0.000	5.000

(U) The Submillimeter Wave Imaging FPA (Focal Plane Array) Technology (SWIFT) program will develop revolutionary component and integration technologies to enable exploitation of this spectral region. A specific objective will be the development of a new class of sensors capable of low-power, video-rate, background and diffraction limited submillimeter imaging. This program will build upon technology developed in the Terahertz Technology Program funded in PE0601101E, Project ES-01.

(U) Program Plans:

- Develop compact, efficient, and high-power THz sources using new electronic and frequency conversion approaches.
- Develop sensitive and large format receiver arrays, advanced integration, and backend signal processing techniques.
- Develop and demonstrate a submillimeter focal plane imager.

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	FY 2003	FY 2004	FY 2005
Direct Analog To Target ID	0.000	0.000	4.000

(U) This program will explore, develop, and demonstrate radical departures from current methods of analog-to-digital (A/D) and digital-to-analog D/A conversion based on uniformly sampled and quantized approximations of analog signals, toward new approaches for extracting higher-level digital information directly from analog signals. The program will pursue thorough and critical application of “off the beaten track” ideas in converters, including signal-class adaptive multiplexing and encoding in analog layer for reduced dynamic range requirements, biologically inspired signal processing and noise reduction, and novel mathematical approaches for discriminating information from interference.

(U) Program Plans:

- Develop broadly applicable methodologies for exploiting novel encoding strategies, closed loop adaptive equalization, integration of sensing and processing, and application-specific knowledge in order to provide revolutionary advances in information conversion.
- Explore novel architectures leveraging intelligent pre-processing based upon space, time, and mathematical transformations of analog measurements and employing cooperative integration of analog and digital processing to obtain required system level performance.
- Work with new classes of quantization devices based on novel “error correcting” representations of numbers, such as beta encoders, phase encoders, geometric invariants.

	FY 2003	FY 2004	FY 2005
Terascale Integration for Scalable Mixed Signal Microsystems	0.000	0.000	4.000

(U) This program will develop semiconductor technologies that provide substantial increases in the integrated performance of entire suites of electronic components that are used for signal generation, detection, and processing, focusing on mixed signal electronics, such as analog/RF/digital chips. This program will result in increased functional densities for highly integrated circuits with low power dissipation, and will pursue innovative nano-scale silicon devices and circuits that will enable precision mixed signal circuits for DoD critical applications.

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(U) Program Plans:

- Develop designs for fiber optic connectors that exploit highly integrated (millions of transistors) of nano-scale devices into mixed signal circuits to open up new approaches to creating precision mixed signal systems-on-chip for processing and generating high performance, tailored signals for DoD applications.
- Identify and exploit new device operational modes and chip microarchitectures to allow high performance, low power, and adaptable/reconfigurable circuits and creating an overall design environment that effectively maps complex system problems into efficient silicon IC solutions.

	FY 2003	FY 2004	FY 2005
Radio Isotope Micropower Sources	0.000	0.000	3.500

(U) This effort will seek to develop the technologies and system concepts required for safely producing electrical power from radioisotope materials for portable and mobile applications, using materials that can provide passive power generation. There will also be research in compact nuclear battery approaches that harness MEMS technology to safely and efficiently convert nuclear energy to either electrical or mechanical power while avoiding lifetime-limiting damage to the power converter caused by highly energetic particles (e.g., such as often seen in previous semiconductor approaches to energy conversion). The goal is to provide electrical power to macro-scale systems such as munitions, unattended sensors, and weapon systems, RF ID tags, and other applications requiring relatively low (up to tens of milliwatts) average power.

(U) Program Plans:

- Develop and demonstrate core technologies of radioisotopes and the manufacturing of alpha and/or beta capture mechanisms to show advances in power output at high conversion factors, material stability, and particle capture in a small form factor with high conversion efficiencies, while operating within safety considerations and limitations.
- Demonstrate reasonable longevity for the chosen nuclear-to-electrical or nuclear-to-mechanical power conversion technique.
- Demonstrate actual, long-lasting power generation by the chosen nuclear-to-electrical or nuclear-to-mechanical conversion method.

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	FY 2003	FY 2004	FY 2005
Photonic Wavelength and Spatial Signal Processing (Photonic WASSP)	7.026	0.000	0.000

(U) The Photonic Wavelength and Spatial Signal Processing (Photonic WASSP) program developed photonic device technologies to allow the dynamic manipulation of both the spectral and spatial attributes of light for sensing, image pre-processing, bio-chemical sensing and general spectral signature analysis.

(U) Program Accomplishments:

- Developed micro-machined optical elements for spectral bands 300 to 500 nm and 3 to 15 microns.
- Initiated integration of the passive elements into beam conditioners.
- Demonstrated integration with packaging module.
- Demonstrated module in a testbed for bio-chemical sensing and spectral imaging.
- Transitioned technology to DoD hypospectral/imaging programs and systems.

	FY 2003	FY 2004	FY 2005
Fabrication of 3D Structures	2.277	2.000	0.000

(U) The goal of the Fabrication of Three Dimensional Structures program is to investigate multi-chip module technology.

(U) Program Plans:

- Continue the development of key technologies behind a packaging concept that uses a stacked multi-chip module approach to reduce interconnect length and increase physical connectivity between layers of electronics.

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	FY 2003	FY 2004	FY 2005
Center for Optoelectronics and Optical Communications	4.743	2.500	0.000

(U) The Center for Optoelectronics and Optical Communications program is investigating advances in optical communications.

- (U) Program Plans:
- Continue optoelectronic and optical communications development.

	FY 2003	FY 2004	FY 2005
Nano Photonic Systems Fabrication	0.947	1.000	0.000

- (U) Program Plans:
- Prepare new materials for applications in lasers and nano-inspired optics.

	FY 2003	FY 2004	FY 2005
Integrated Nano and Micro-manufacturing	0.000	1.000	0.000

- (U) Program Plans:
- Initiate development of advanced nano and micro-manufacturing technologies.

(U) **Other Program Funding Summary Cost:**

- Not Applicable.

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COST (In Millions)	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	FY 2008	FY 2009
Cryogenic Electronics MPT-06	6.895	4.911	0.000	0.000	0.000	0.000	0.000

(U) **Mission Description:**

(U) Thin-film electromagnetic materials have reached a stage of development where specific applications can be identified in electronic devices and circuitry for military systems. Films may be deposited and patterned to form electromagnetic components in ways that are similar to, and compatible with, the processes of conventional semiconductor manufacturing. Such electromagnetic components, as well as complementary metal oxide semiconductors (CMOS), work best at lower temperatures, so that cryogenic packaging generally will be required for optimum performance. Thin-film high temperature superconducting (HTS) components packaged with cryogenic devices are being applied to radars, electronic warfare suites, and communications systems to enhance performance by more than an order of magnitude while reducing size and power requirements. Particular demonstrations include detection and geolocation of targets of high interest based upon low-level characteristic emissions and communications receivers with greater immunity to interference. Highly dependable and inexpensive cryocoolers are also being developed for these applications. These latter development efforts include the exploration of techniques to improve the performance of solid-state thermoelectric materials and devices in applications ranging from communications to power generation. This project draws to a close at the end of FY 2004, a reflection of the maturity level that DARPA has obtained in cryogenic electronic technology development and sub system insertion. Any further integration of this technology into weapon/sensor systems will be budgeted in the respective platform's PE and projects.

(U) **Program Accomplishments/Planned Programs:**

	FY 2003	FY 2004	FY 2005
Totally Agile Sensor Systems (TASS)	4.149	0.000	0.000

(U) The sensitivity of a standard radio receiver for the detection of small signals in an interfering background can be enhanced up to 10X, by the insertion of a high temperature super conducting (HTS) filter at the input of the receiver. Such ultra-sensitive receivers, mounted on military aircraft, ships and ground installations, have proven to be highly effective for SIGINT and COMINT missions. The Totally Agile Sensor Systems (TASS) program has demonstrated frequency tunability of HTS filters up to 30% of base frequency, thereby providing greater agility to cover the

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frequency spectrum. The final phases of the TASS program were directed toward enhancing performance even further in terms of sensitivity and selectivity, by narrowing the bandwidth of the HTS filter by 10-100X, while maintaining tunability. Such capability has vastly improve overhead SIGINT collection in a spectrally-crowded environment.

(U) Program Accomplishments:

- Fabricated novel HTS filters with ultra-high quality factor (Q) and 0.1% bandwidth.
- Incorporated agile front-end pre-selector modules utilizing tunable high-Q HTS filters within standard receivers.
- Demonstrated totally agile sensor systems with ten times SIGINT and COMINT capability.
- Adapted ultra-high Q and tunability for demonstration in a receiver console, with features for sweep rate and filter reconfiguration.
- Transitioned capability for 30 percent tunability to RC-135 aircraft demonstration.

	FY 2003	FY 2004	FY 2005
Rapid Identification and Targeting (RAPIT)	2.746	2.411	0.000

(U) The goal of the RAPIT program is to develop a method of detection, identification and location of hidden threat forces which are not emitting radiation and are not discernable by present technical means. In the context of a network centric model, utilizing lightweight and lightly-armored systems, a probable threat is a foot soldier (dismount) with a rocket propelled grenade or similar weapon. Since it is likely that he will be carrying a radio or other communications gear, it is possible to detect and identify the radio by (1) its emission in standby mode (leakage), or (2) an induced nonlinear RF return if appropriately stimulated (stimulated leakage), even when the radio is unpowered. Both these techniques were originally demonstrated within the DARPA TASS program utilizing RF receivers with tunable HTS front-end filters. Only tunable HTS front-end filters have the necessary sensitivity and selectivity for low-level RF signals detection. Detection ranges of over 2 Km are possible in the near-term. The RAPIT technique will be fully developed and quantified for all likely threats, and a targeting system will be assembled.

(U) Program Plans:

- Measure radio frequency emission characteristics of generic components, active and passive modes, on bench top and in anechoic chambers.
- Determine range projections for target detection, based upon initial measurements and likely scenarios.
- Evaluate clutter, intermodulation distortion and propagation effects on targeting.

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- Demonstrate detection of specific targets from an airborne platform.
- Evaluate detection and geolocation of multiple targets and target classes.

	FY 2003	FY 2004	FY 2005
Cryo-power for the All Electric Ship	0.000	2.500	0.000

(U) This effort will leverage the success of the Cryogenics Electronics project and apply it to the development of a test bed for cryo-electronic components for power systems, particularly those of interest to the Navy for their all-electric ship program.

- (U) Program Plans:
- Develop and test cryogenic semiconductor switching elements, cryogenic cables and superconducting passive elements including tape, inductors and transformers.

(U) **Other Program Funding Summary Cost:**

- Not Applicable.

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COST (In Millions)	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	FY 2008	FY 2009
Beyond Silicon MPT-08	80.152	83.976	61.827	34.570	28.657	16.000	16.000

(U) **Mission Description:**

(U) The phenomenal progress in current electronics and computer chips will face the fundamental limits of silicon technology in the early 21st century, a barrier that must be overcome in order for progress to continue. The Beyond Silicon project explores alternatives to silicon based electronics in the areas of new electronic devices, new architectures to use them, new software to program the systems and new methods to fabricate the chips. Approaches include nanotechnology, nanoelectronics, molecular electronics, spin-based electronics, quantum-computing, new circuit architectures optimizing these new devices, and new computer and electronic systems architectures.

(U) The Beyond Silicon project is investigating the feasibility, design, and development of powerful information technology devices and systems using approaches to electronic device designs that extend beyond traditional Complementary Metal Oxide Semiconductor (CMOS) scaling, including non-silicon based materials technologies, to achieve low cost, reliable, fast and secure computing, communication, and storage systems. This investigation is aimed at developing new capabilities; from promising directions in the design of information processing components using both inorganic and organic substrates, designs of components and systems leveraging quantum effects and chaos, and innovative approaches, to computing designs incorporating these components for such applications as low cost seamless pervasive computing, ultra-fast computing, and sensing and actuation devices.

(U) **Program Accomplishments/Planned Programs:**

	FY 2003	FY 2004	FY 2005
Quantum Information Science and Technology (QuIST)	20.693	27.268	23.980

(U) The Quantum Information Science and Technology (QuIST) program will explore all facets of the research necessary to create a new technology based on quantum information science. Research in this area has the ultimate goal of demonstrating the potentially significant advantages of quantum mechanical effects in communication and computing. Technical challenges include loss of information due to quantum

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decoherence, limited communication distance due to signal attenuation, limited selection of algorithms and protocols, and scalability to large numbers of bits. Error correction codes, fault tolerant schemes, and longer decoherence times will address the loss of information. Signal attenuation will be overcome by exploiting quantum repeaters. New algorithm techniques and complexity analysis will increase the selection of algorithms, as will a focus on signal processing. Scalable solid-state technologies will integrate thousands of qubits on a single device. Expected impacts include highly secure communications, algorithms for optimization in logistics and wargaming, highly precise measurements of time and position on the earth and in space, and new image and signal processing methods for target tracking. Additionally, QuIST will also pursue a focus effort to build and demonstrate a scalable quantum information processor that will address issues such as architecture and manufacturability.

(U) Program Plans:

- Determine quantum architecture and design solutions for problems such as graph isomorphism, imaging, and signal processing.
- Investigate alternative protocols for secure quantum communication, quantum complexity, and control.
- Investigate the use of quantum information in metrology.
- Demonstrate improved single and entangled photon sources and detectors.
- Investigate alternative designs, architectures and devices for quantum communication, computation, and memory; demonstrate low overhead, fault tolerant solid state quantum bit (qubit) memory and gates with at least two entangled qubits.
- Employ scalable qubit architectures to demonstrate an application of interest to the DoD (e.g., quantum repeater).
- Refine and integrate quantum communications systems into existing DoD and intelligence community networks.

	FY 2003	FY 2004	FY 2005
Polymorphous Computing Architecture (PCA)	15.012	16.992	14.074

(U) The Polymorphous Computing Architectures (PCA) program is developing a revolutionary approach to the implementation of embedded computing systems to support reactive multi-mission, multi-sensor, and in-flight retargetable missions, and reduce payload adaptation, optimization, and verification from years to days to minutes. Current DoD embedded computing systems can be characterized as static in nature, relying on hardware-driven, heterogeneous point-solutions that represent static architectures and software optimizations. The program breaks the current development approach of hardware first and software last by moving beyond conventional silicon to flexible polymorphous computing systems. The key efforts of this revolutionary step forward in embedded computing systems are: 1) define critical reactive computing requirements and critical micro-architectural features; 2) explore, develop and prototype reactive polymorphous computing concepts; 3) explore,

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develop and prototype multi-dimensional verification and validation techniques for dynamic reactive missions; and 4) provide early experimental testbeds and prototype polymorphous computing systems. The result will be an embedded computing processing capability that will be mission and technology invariant yet highly optimizable for each new mission instantiation, thus providing for tactical and strategic mission tempo opportunities as well as technical upgradeability over the life of the computing system. Based on an average of four major upgrades over a 30 year period, significant saving of up to 45 percent in development and deployment costs may now be achieved over the life of a typical DoD embedded computing system by applying this technology. The program will also develop interactive, real-time terrain computation, visualization, and manipulation to support Computer Generated Forces (CGFs), specifically the OneSAF (One Semi-Automated Forces). This effort will leverage commercial graphic processing units (GPU) and early PCA program streaming technology to provide key technology transitions.

(U) Program Plans:

- Characterize and perform functional decomposition of pivotal reactive system algorithms and computing functions.
- Develop multi-dimensional reactive computing optimization, verification techniques.
- Model, simulate and characterize complete candidate polymorphic computing systems including hardware elements, morphware, run-time systems, and tools.
- Perform early small scale proof-of-concept testing, integration and evaluation of early polymorphic computing architecture prototypes.
- Demonstrate and quantify the potential of full up polymorphic computing architecture systems for the DoD and their complementary commercial viability.
- Select, develop, and perform a DoD risk reduction effort for a multi-mission application.
- Develop line-of-sight and collision computations using GPU.

	FY 2003	FY 2004	FY 2005
Antimonide Based Compound Semiconductors (ABCS)	9.870	9.346	0.000

(U) This program will develop low power high frequency electronics circuits and infrared (IR) sources based on the Antimonide family of compound semiconductors (ABCS). Specific IR source goals include operating above thermoelectric cooled temperatures and greater than 10 percent efficiency with continuous wave (cw) in the Mid-Wave Infrared (MWIR) and single mode cw operation in the Long-Wave Infrared (LWIR).

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(U) Program Plans:

- Substrate Technology. Accelerate recent breakthroughs in lateral epitaxial overgrowth and thin film delaminating and rebonding to develop a source for ABCS substrates with essentially any desired thermal and/or electronic property.
- Electronics Integration. Raise levels through a series of demonstrations of analog, digital or mixed signal circuits with increasing device count which have beyond state-of-the-art performance in terms of frequency of operation and low power consumption.
- Demonstrate robust semi-insulating ABCS substrate material.
- IR sources. Exploit the unique bandgap engineering approaches available with the ABCS family of materials to increase the operation temperature above 230 degrees Kelvin and extend emission over the Long-Wave Infrared (LWIR) range.
- Achieve multi-watt output, array technology along with increases in efficiency for individual devices.
- Deliver first six multi-batch ABCS substrates.

	FY 2003	FY 2004	FY 2005
Integrated Mixed Signal (A/D) and Electronic/Photonic Systems (NeoCAD)	12.056	8.987	0.000

(U) The Integrated Mixed Signal (A/D) and Electronic/Photonic Systems (NeoCAD) program will develop and demonstrate innovative approaches to Computer Aided Design (CAD) of Mixed Signal (Analog/Digital) and Mixed Electronic/Photonic systems. The goal is to enable the design and prototyping of ultra complex microsystems with a high degree of integration and complexity for both military and commercial applications.

(U) Program Plans:

- Develop Model Order Reduction methods (for analog and photonic devices) to enable the creation of behavioral models.
- Develop and demonstrate top-down design capabilities for analog, mixed signal and mixed electronic/photonic systems that match the efficiency currently achieved with digital designs.
- Develop fast solvers for analog and photonic devices; perform non-linear model order reduction, develop extraction tools, synthesis and layout capabilities for mixed signal and mixed electronic/photonic circuits, develop interfaces with existing digital tools to enable co-simulation.
- Demonstrate the tools for designing and prototyping selected mixed electronic/photonic circuits and mixed signal systems (e.g., Analog-to-Digital Converters) for military applications.

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- Develop a design methodology for analog, mixed signal and mixed electronic/photonic systems utilizing:
 - Analog behavioral models in a digital design environment.
 - Extraction methodologies for analog and photonic devices.
 - Synthesis and layout rules for analog and photonic devices.
 - Hierarchical design libraries.

	FY 2003	FY 2004	FY 2005
Moletronics	22.521	11.330	0.000

(U) The molecular electronics (Moletronics) program is demonstrating that integration of multiple molecules, nanotubes, nano-wires, etc., into scalable, functional devices that are interconnected to the outside world will enable lower power operation, a wide range of operating temperatures and much greater device density. This research will also demonstrate the scalability of molecular scale electronics to circuits containing 10^{11} elements and for densities equivalent to $10^{11}/\text{cm}^2$ and show that hierarchical self-assembly processes can be employed to build molecular circuits.

- (U) Program Plans:
- Characterize and optimize molecular-based devices such as switches, multi-state molecules and molecules exhibiting highly non-linear characteristics such as negative differential resistance.
 - Demonstrate that nano-wires have conductivities near that of bulk metal or better.
 - Quantify the defect-tolerance required for a molecular-based computer to still function.
 - Develop hierarchically directed assembly processes to assemble molecular devices, wires and interconnects.
 - Demonstrate efficient defect-search algorithms.
 - Model the scalability of molecular circuit architectures to high counts and high device densities.

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	FY 2003	FY 2004	FY 2005
Applications of Molecular Electronics (MoleApps) (formerly Molecular Computing)	0.000	10.053	10.020

(U) The goal of the MoleApps program is to extend the capabilities being developed in the current Moletronics program to demonstrate the computational processing capabilities of molecular electronics in a system that integrates memory with control logic and data paths. A demonstration processor will be designed and built that can interpret a simple high-level language. This approach will allow the use of a simpler processor designs to demonstrate the advantages of nano-scale molecular electronics that do not have the conventional circuitry overhead associated with modern pipeline chip designs.

(U) Program Plans:

- Construct combinatorial logic functions assembled from molecular-scale components.
- Use small-scale integration (SSI) to build combinatorial logic functions using molecular-scale components.
- Construct sequential logic/Finite-state machine assembled from molecular-scale components.
- Add registers or latches in communication with combinatorial logic arithmetic functions.
- Use medium-scale integration (MSI) to construct sequential logic/finite-state machine assembled from molecular-scale components.

	FY 2003	FY 2004	FY 2005
Focused Quantum Systems (FoQuS)	0.000	0.000	13.753

(U) The FoQuS program will develop a path towards an advanced quantum factoring machine drawing on the fundamental understanding and foundations developed under the QuIST program also funded in this project. Key elements for such a processor include architectural development, quantum memory, input/output (I/O) interfaces, state synthesizers, and nanofabrication of materials and devices. The specific goal of the program is to significantly accelerate the development of a quantum computer, with the aim of building a quantum processor in a decade rather than a score of years, as projected by the current roadmap.

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- (U) Program Plans:
- Develop solid state and other potentially scalable technologies.
 - Leverage substantial investment already made by semiconductor industry in materials infrastructure.
 - Develop industry participation to provide the discipline necessary for ultimate manufacturability of a quantum processor.
- (U) Other Program Funding Summary Cost:
- Not Applicable.

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COST (In Millions)	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	FY 2008	FY 2009
Biologically Based Materials and Devices MPT-09	65.321	77.997	89.858	96.402	82.169	86.093	78.017

(U) **Mission Description:**

(U) This project acknowledges the growing and pervasive influence of the biological sciences on the development of new materials, devices and processes as well as the commensurate influence of materials, physics and chemistry on new approaches to biology and biochemistry. Contained in this project are thrusts in the application of biomimetic materials and devices for Defense, the development of biochemical materials to maintain performance, the development of multifunctional transducers based on biological membranes, the application of magnetic materials in biological applications, and the development of manufacturing tools that use biological components and processes for materials synthesis.

(U) **Program Accomplishments/Planned Programs:**

	FY 2003	FY 2004	FY 2005
Bioinspired and Bioderived Materials	30.728	35.297	38.000

(U) The Bioderived Materials thrust explores the application of biomimetic principles to materials and devices of interest to the DoD. Specifically, the unique characteristics of biologically derived materials and devices will be exploited through understanding, control and emulation of the structure and chemistry of the interface between man-made and biotic materials. This includes an effort to develop synthetic optics that mimics the advantages and adaptability of biological lenses. Other efforts seek to understand the principles of locomotion and sensing capabilities of biological organisms and implement them in man-made materials for robotics and other Defense applications. Also, the fundamental operating principles of biomolecular motors will be developed and exploited for designing nano- to macro-scale devices having unparalleled energy efficiency. Finally, the physical interfaces necessary for interacting and controlling biology will be developed and exploited.

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(U) Program Plans:

- Explore soft materials (e.g., actuators, adhesives) in biological systems for potential Defense applications.
- Demonstrate biomimetic sensory prototypes that collect electromagnetic olfactory and visual inputs.
- Define new, malleable materials for coordinated appendage function in land, water, and air platforms that utilize biomimetic principles of design (e.g., emulate skin, bone, muscle, nerve endings and self repair features) for locomotion and actuation.
- Explore new bioinspired locomotion in robotic systems and develop power efficient, systems level bio-locomotion for mobility in rough/loose terrain and in environments not usually used for locomotion, i.e., vertical ($>60^\circ$) and inverted surfaces.
- Demonstrate a material system based on bio-inspired optics technology that can produce a reversible change in the index of refraction of 1.0 point over a bandwidth of at least 50 nanometers with 95% or better transmittance allowing a re-configurable optical system that is capable of changing between wide angle (120 degrees) and narrow field of view within a frame rate.
- Develop bio-inspired optical components and filters based on novel materials chemistry, and directed self-assembly principles that guide unique hierarchical structure.
- Determine and quantify the mechanism of motor function, motor performance, and efficiency for several types of biomolecular motors through computational models and experimental measurements.
- Isolate, modify, and integrate biomolecular motors with synthetic/inorganic materials to demonstrate devices with unique energy conversion capabilities and potential DoD utility.
- Exploit stealthy sentinels, including the development of critical materials/device interfaces to address teleoperation and autonomous navigation, for their ability to be remotely guided to operationally relevant sites and generate environmental information (chemical, biological, visual).
- Develop signal transduction technology that directly converts biological macromolecular activity (sensing/binding/conformation changes) into an appropriate electrical or optical signal output for the development of biomimetically based sensors (uncooled IR, optical, etc.).
- Develop material systems based on biological principles that distribute the force and displacement capability of a hydraulic system continuously throughout a structure.

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	FY 2003	FY 2004	FY 2005
Biochemical Materials	30.593	24.000	32.000

(U) The Biochemical Materials thrust examines how breakthroughs in the understanding of biochemistry can drastically improve the survivability of soldiers. For example, examining the biochemistry of the brain during sleep deprivation can lead to new approaches for maintaining the cognitive function of soldiers in the face of sleep deprivation. The application of biochemical principles can also lead to techniques to allow the principles of biological organisms that survive in extreme environments to be exploited for the preservation of tissue and cells of interest to DoD. Finally, the modeling of the biochemical behavior of organs and tissues can lead to significant advances in the medical treatment of the soldier on the battlefield. This effort is supported by basic research on fundamental biological mechanisms in PE 0601101E, Project BLS-01.

- (U) Program Plans:
- Demonstrate induced desiccation strategies for platelets and red blood cells that allow prolonged periods (> 24 months) of dry storage and recovery.
 - Develop new approaches for increasing the availability of blood products.
 - Develop self-care medical technology to enable the warfighter in the battlefield to accelerate wound healing, internal clotting and pain relief to increase a soldier's survivability on the battlefield.
 - Develop an understanding of the biochemical and physiological causes of decreased cognitive performance during sleep deprivation through studying animal model systems, synaptic function, and transcranial magnetic stimulation (TMS).
 - Demonstrate and validate approaches to develop biomaterials and other concepts that extend the cognitive performance capabilities of warfighters during extended periods of sleep deprivation and stress.
 - Develop methods for maintaining functional and physiokinetic endurance by nutritional and physical methods that are rapidly inducible, reversible and minimize the need for caloric intake while maintaining both strength and endurance.
 - Develop methods for regulating core body temperature to maintain physical performance and endurance when training.
 - Demonstrate the capability to transfer biochemical processes chemically or physically to cells, tissues, organs, systems, and organisms lacking robust survival mechanisms.

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- Demonstrate full 3-D visual image representation carried on electronic dog tag that can be used to predict likelihood of survival from potentially lethal battlefield wound.
- Define and demonstrate new operating room technologies for the battlefield.

	FY 2003	FY 2004	FY 2005
Bio-Fabrication (Formerly REMEDE)	0.000	7.000	9.000

(U) The Bio-Fabrication (B-FAB) program will demonstrate the feasibility of using biological processes and artificial membranes as a new nanofabrication toolset to synthesize and manufacture chemicals, materials, and devices of high value to the DoD. Specific targets for demonstration within this program include scalable technologies for electronic materials and devices (ultra-low-k dielectrics; GaN-InGa_N-AlGa_N and InP-GaP-AlP-AlInGaP materials, Rf and photo-emissive devices), mechanical materials (super-tough fibers and associated composites), and site-directed-synthesis (in-package device fabrication). Key elements of this program include the development and utilization of biological components and/or processes for the fabrication of device-grade quality electronic/optical/mechanical materials, further developing these processes for electronic or optical doping, site-directed synthesis, and nanostructure process control, and finally the integration of the B-FAB process capabilities with current micro- and nano-fabrication tools for the fabrication of full-scale integrated electronic, optical, or mechanical proof-of-technology devices.

(U) Program Plans:

- Develop bioenabled routes for the fabrication of relevant electronic, optical, or structural materials. Demonstrate the essential capacity for the fabrication of these materials at the scale of interest (e.g., single crystal GaN, 1 micron by 1 micron by 100 nm).
- Develop computational, fabrication, and process control tools for the design, manipulation, and optimization of the biocatalytic, enzymatic, bio-pathway, or organisms with the target synthetic properties necessary for the fine-scale manipulation of biosynthetic fabrication.
- Develop and demonstrate the capability to produce bio-fabricated materials with chemically and/or spatially modulated properties, possibly including controlled doping (n-type, p-type), stacked nano-layers, quantum dots, or 3-D articulated structures in a candidate electronic, optical, or mechanical device material.
- Demonstrate the integrability of biosynthetic fabrication processes with current fabrication and/or micro-fabrication toolsets.

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- Design, develop, and demonstrate integrated biosynthetic fabricated electronic, optical, or mechanical devices with improved or otherwise unattainable performance or cost characteristics.
- Develop device architectures capable of accelerating protein identification by over two orders of magnitude in time reduction.

	FY 2003	FY 2004	FY 2005
Bio-Magnetic Interfacing Concepts (BioMagnetICs)	4.000	10.000	10.858

(U) The Bio-Magnetic Interfacing Concepts (BioMagnetICs) Materials program will develop and demonstrate novel capabilities for integrating nanomagnetism with biology and will demonstrate the advantages of magnetism as a powerful new transduction mechanism for detecting, manipulating, and controlling biological function in single cells and biomolecules. The state-of-the-art research “tools” that have allowed researchers to observe the most fundamental units of biology (cells, DNA, proteins, etc.) do not possess the resolution, precision, or high throughput capacity to enable manipulation and/or functional control of large numbers of cells and biomolecules. Such a capability would have a pervasive and paradigm shifting impact on future military and civilian applications of biotechnology including chem-bio detection, therapeutics, and medical diagnostics. Nanoscale magnetism offers the promise of a robust, non-invasive, non-destructive, multiplexing, and high throughput interface that is compatible with the nanometer scale at which the biochemistry of cellular function exists. This effort is supported by basic research on fundamental biological mechanisms funded in PE 0601101E, Project BLS-01.

(U) Program Plans:

- Develop and demonstrate a portable, magnetism-based DNA detection and readout capability for rapid determination of specific biological warfare agents.
- Develop and demonstrate a capability for non-invasive, non-destructive imaging of intracellular activity.
- Develop and demonstrate remotely addressable, magnetism-based biochemical sensors.
- Develop and demonstrate the capability to magnetically manipulate and actuate cellular functions such as apoptosis, reproduction, and gene expression.
- Develop and demonstrate the capability to use magnetism to rapidly filter biotoxins from humans.

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	FY 2003	FY 2004	FY 2005
University of Florida Biosensor/Biomotive Nano Technology	0.000	1.700	0.000

(U) Convert innovative research into methodologies for designing, fabricating and demonstrating different kinds of novel bio-molecular assemblies that form transducing elements between chemical, electrical, optical and mechanical phenomena.

(U) **Other Program Funding Summary Cost:**

- Not Applicable.